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FURTHER NOTES ON THE EARTHWORMS OF THE ARNOLD ARBORETUM, BOSTON

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An opportunity to search once more for mature specimens of the *Pheretima* sp., represented in collections of the previous spring by a single, specifically unidentifiable juvenile, was unexpectedly provided on September 25, 1952. After securing the desired material, as many of the previous sites as time permitted were re-examined, to permit comparison of fall with spring populations.

In the natural woods, during the summer, the leaf pile of previous collections had been grown over and had become rather dry. Some fifty feet away, and at about the same distance from the site where the juvenile of *Pheretima* sp. had been found, another large leaf pile, possibly older and with more gravel, had remained damp and without any plant overgrowth. In the peat bog, where vegetation had been mowed and removed, water was no longer running in the brook though still standing in small, scattered puddles, but previously disturbed soil still seemed moist. In the ponds, water level had fallen several inches exposing a marginal strip of bottom muck that was still saturated. The Newton garden had been planted and could not conveniently be re-examined.

The species obtained in the September collections are listed in the following table which also shows sexual stages and number of specimens secured.

EARTHWORMS OBTAINED IN THE ARBORETUM IN SEPTEMBER, 1952

Species	Original Leaf Pile	Natural Woods		Peat Bog
		Near Side	Far Side	
<i>Allolobophora</i>		†	*	
<i>arnoldi</i>	0-2-2	0-1-0	0-0-1	0-0-1
<i>caliginosa</i>	0-0-2			0-0-1
<i>limicola</i>				0-2-0
sp. (1)	4-0-0-0			
<i>Dendrobaena</i>				
<i>subrubicunda</i>	3-5-32	1-0-1		
<i>Eisenia</i>				
<i>foetida</i>	12-5-6	7-1-7	2-0-1	
<i>Lumbricus</i>				
<i>castaneus</i>	0-0-2			
<i>rubellus</i>	3-1-7	2-2-3-16	6-11-17	
<i>terrestris</i>	4-1-0-4		1-0-1	
<i>Octolasion</i>				
<i>lacteum</i>				0-0-1
<i>Pheretima</i>				
<i>agrestis</i>		0-0-35	0-0-21	

Figures indicate juvenile-acitellate-clitellate or small juvenile-late juvenile-acitellate-clitellate.

† Postsexual acitellate.

* Specimen in poor condition.

(1) Probably of *arnoldi* and/or *caliginosa*.

A. arnoldi. Two specimens from original leaf pile listed as clitellate had spermatophores externally but the clitellum had almost completely regressed, the site being indicated only by a brownish discoloration. In an amputee from the bog, after enteroparietal healing at 106/107, cvi had been much elongated and at the same time narrowed so as to taper terminally and its setae had been lost though follicle apertures were still visible. One worm from the leaf pile showed the same changes in its last segment.

L. terrestris. A small juvenile from the leaf pile, 27 x 2.5 mm. has 149 segments.

O. lacteum. Segments in front of the anus were packed with coelomic corpuscles and parasitic bodies many of which were discharged through dorsal pores during preservation.

DENDROBAENA SUBRUBICUNDA (Eisen) 1874

Clitellum, on xxvi-xxxi but occasionally with slight extension onto xxxii (32 + 26), xxvi-xxxii (1). Epidermis of xxv (several + 8) and xxxii (several) slightly modified. Tubercula pubertates, on xxviii-xxx (35 + 27), occasionally reaching onto xxxi. Each tuberculum nearly always is bounded laterally by a deep groove. In two clitellate specimens in which tubercula were quite indistinguishable the groove was obvious, on both sides of the body. The tuberculum is longitudinally elliptical in outline. A central depressed portion of similar outline may be more or less clearly demarcated from a band-like marginal area by a slight groove, or, instead, there may be recognizable only a single longitudinal groove at the center. The lateral groove, in some specimens, apparently passes, though less clearly, around ends of tuberculum to become completely circumferential. Genital tumescences, including *ab*, on viii (5), ix (14 + 11), x (5), xvi (33 + 27), xvii (2 + 1), xviii (1), xx (3), xxi (1), xxii (+1), xxiii (+2), xxiv (12 + 12), xxv (1 + 3), xxvi (+1), xxvii (26 + 25), xxviii (2), xxxi (19 + 23), xxxii (1), xxxiii (+1), xxxiv (+1), xxxv (+1). Tumescences on xvi may extend well into *bc* and *aa* or even be united mesially. Those on xxxii to xxxv are especially well developed.

Homoeosis. Male pores, on xvi. Female pores, on xiv. Clitellum, on xxvi-xxxii and on xxxiii-xxxiv of left side only. Tubercula pubertates, on xxviii-xxx (right side), xxix-xxxiii (left side). Genital tumescences, on left sides of xxiv and xxxiv. No metameric abnormality recognized.

Remarks. In live worms a short terminal region had a brilliant yellow appearance that disappeared during preservation and which, presumably, was due to accumulations of coelomocytes in the coelomic cavities of a region with rather transparent parietes. The anal region was not marked off by an intersegmental furrow from the last setigerous segment in 19 specimens. Spermatophores were present externally on eight specimens.

Data from a series of 27 specimens (collected at Bangor, Maine) that has been available for comparison with arboretum worms, are included in parentheses above, preceded by the + sign. Very little of such information has been reported.

LUMBRICUS RUBELLUS Hoffmeister 1845

Number of segments: 67, 73, 75, 79, 85, 88, 91, 96, 100, 101, 109 (2), 110, 111, 112 (4), 113 (3), 114 (3), 115 (2), 116 (3), 117 (4), 118 (3), 119 (4). Clitellum, on xxvii-xxxii (40). Tubercula pubertates, on xxviii-xxxi (5), but extending onto xxvii (40). Genital tumescences, including *ab*, on vi? (1), vii? (1), viii (2), x (6), xi (42), xii (50), xxvi (56), xxvii (3).

Abnormality. No. 1. One segment near the hind end split, on opposite side, into three segments each with setae. No. 2. Two metameric abnormalities in region shortly in front of anus.

Homoeosis. No. 1. Male pores, as well as female, on xiv. No. 2. Male pores on xvi, female pores on xiv. Clitellum on xxvii-xxxii, tubercula on xxviii-xxxi but extending onto xxvii. Genital tumescences, on xxvi, and possibly also (?) on vii-xiii. No. 3. Female pores on right side of xiii and left side of xiv. Male pores on right side of xiv and left side of xv. Aclitellate, tubercula on right side of xxvi-xxx and left side of xxvii-xxxi. Genital tumescences, on right sides of ix and xxv, left sides of x and xxvi.

Remarks. Worms with 79, 88, and 100 segments have large nephropores, pit-like depressions at sites of apertures of setal follicles but no setae on the last segment, and probably were amputees. Two specimens, of 109 and 119 segments, had setae in the last segment and presumably were also amputees. If any of the other worms having 67 to 101 segments are amputees, no indications thereof were recognized and the terminal region must have been subsequently reorganized so as to look like that of a normal worm.

In the clitellar region, intersegmental furrows are always more or less clearly indicated. The worms can be arranged in a finely graded series of stages showing gradual deepening of the furrows, decrease in thickness of the epidermis, reappearance of dorsal pores, and gradual reddening of the parietes. In the final stage, boundaries of the clitellum were not certainly determinable but in much of the clitellar region the red color has a sort of slight whitening that is lacking on other segments. No spermatophores were found. No brownish discoloration such as is present in the clitellar region of postsexual specimens of some species, was recognized in any of the worms.

Smith (1917) and Olson (repeatedly) have given the number of

segments in this species as 95 to 150 or 90 to 145, but with no data as to individual counts in American specimens. Segment numbers in all of the arboretum collections are in better agreement with those of English worms, 95 to 120, as reported by Cernovitov and Evans (1947).

PHERETIMA AGRESTIS Goto and Hatai 1899

External characteristics. Length, 70–150 mm. Diameter, 5–8 mm. Number of segments: 63 (3***), 64 (*), 66 (2**), 67, 69 (*), 71, 76, 77, 78 (2**), 82, 84, 85 (*), 86, 90, 92 (2**), 95, 97 (2), 98 (2), 99 (3), 100 (7), 101 (6), 102 (7), 103 (5), 104 (1). First dorsal pore, on 12/13 (56); a dark and somewhat pore-like marking shortly behind 11/12 on several specimens, definitely on 11/12 though not a functional pore, in one worm. Setae: 52, 55, 56, 62, 62, 64, 64, 65, 69/xii; vii/2, 4, 4, 3, 4, 2, 1, 1, 1, 2, 2, 4, 2, 4, 4, 1, 2, 1, 3, 2, 2; viii/5, 3, 5, 1, 2, 2, 3, 0, 2, 2, 2, 5, 3, 4, 3, 0, 0, 0, 1, 1. (Clitellum, on xiv–xvi; annular.)

Sexthecal, spermathecal pores minute and superficial, on 5/6–7/8, about $\frac{1}{2}$ C apart. Each pore may be at center of a definitely demarcated circular porophore or the latter may have the appearance of two semi-circles, one in front of and the other behind the pore. (Female pore, single, median, on xiv.) Male porophores, male pores, as well as any rudiments thereof, completely lacking.

Definite genital markings also are lacking. The setal circles of vii–viii are uninterrupted (several specimens), or have a small gap on one side (several) or one large median gap which may extend nearly to spermathecal pore lines (25), or a pair of gaps leaving a few setae midventrally (as indicated above). In the latter case, in ten specimens, in region of each setal gap there is recognizable, in good optical conditions, an area where the epidermis is thin or especially cross-hatched with fine furrows. These areas, which have no definite boundary though appearing to be of transversely elliptical outline, are symmetrically placed across the setal equator. No special pigment, brown or otherwise, was recognized in any of those areas.

Internal anatomy. A low collar of iridescent tissue is present on the oesophagus just behind the gizzard. The intestine begins in xv (6) and has a double row of sacculations on each side from about xvi to about xxv, the ventral row on each side usually more definite than the dorsal and with one or more of the sacculations so constricted as to have an appearance of dorsally directed pockets. The caeca are mani-

cate, with seven or eight secondary caeca, the dorsalmost the longest. The typhlosole, which begins in the region of the caecal segment, is low, simply lamelliform and from about xxxix gradually decreases in height, becoming more irregular in shape and finally unrecognizable behind lxvi (worm of 92 segments), lxxiv (100, 104 segments), lxxvii (102 segments). A very small but definite and double ridge runs posteriorly on the floor of the gut from the caecal metamere for fifteen or twenty segments.

Last hearts in xiii (5), heart of ix on left side (3) or right side (2), hearts of x lacking (5). Subneural trunk much smaller anterior to xiii but continued into ii. The dorsal trunk of one specimen passes superficially through tissues of the pharyngeal bulb and on emerging anteriorly bifurcates under the brain, the branches passing around the gut median to the nervous commissures and reuniting midventrally to become the ventral trunk.

Testis sacs unpaired, apparently above the nerve cord and with ventral blood vessel in, on or just above the roof. Testes present, male funnels large and nearly filling the sacs which have very little coagulum. Seminal vesicles laterally flattened, filling coelomic cavities of xi and xii, reaching into contact with dorsal vessel, in xii with a primary ampulla marked off distinctly from the lamina. Vasa deferentia, in region of xvi to xxiv, slightly swollen for a short distance and ending blindly without passing into parietes. No trace of male terminalia. Ovaries appear to be unusually large.

Spermathecal ducts shorter than contracted ampullae, with thick wall (having a muscular sheen), abruptly narrowed at parietes, lumen in coelomic portion large, irregularly slit-like in cross section as a result of presence of high longitudinal ridges. Diverticulum longer than combined lengths of duct and ampulla, into median face of duct close to parietes, with slender stalk (having muscular sheen) longer than the duct and a longer, more or less sausage-shaped seminal chamber.

Distribution. Japan: Takahashi, Tokorosawa, Oarai, Sapporo, Hokkaido, Sendai, Oshima Island, Matsuyama, Tomitaka, Kago-shima. Said to be widely distributed throughout the Aomori and Iawati prefectures. *P. agrestis* has been reported once before outside of Japan and then from Baltimore but several attempts to secure specimens for confirmation of the identification have been fruitless.

Abnormality. Specimen of 82 segments with one metameric abnor-

mality in region of lii. First dorsal pore on 12/13 but a definitely pore-like though obviously non-functional marking exactly on 11/12. Left spermathecal pore of 7/8 and clitellum on right side of xiv lacking. Female pores: on left side of xiii, in setal circle, and on right side of xv. Heart present in xiv on right side. A testis on posterior face of left rudiment of 8/9, a male funnel on anterior face of left rudiment of 9/10 (no testis sac but sacs and vesicles of x-xii as usual. Left ovary lacking but a rudimentary female funnel present in left side of xii; right ovary and female funnel in xiv. Vas deferentia end blindly in xxiv.

Autotomy and Regeneration. On being touched three worms instantly autotomized a posterior portion (of 31, 34, 35 segments). In one case autotomy was either through lxiv or at 64/65. In a specimen of 85 segments, lxii-lxiii were deeply constricted all around the body but apparently without recognizable break in the musculature. Posterior amputees are indicated above by asterisks after setal numbers (one for each amputee). Specimens with 63, 69, 77, 78, 86, 90 and 92 segments each have an anal region that is not marked off by an intersegmental furrow from a terminal segment with a complete circle of setae. The last metamere in a 78-segment worm (a) is unusually long, without setae, but with minute pits still representing sites of apertures of original follicles. A similar long terminal metamere but without setal pits characterizes a worm (b) of 76 segments but in this case setae are recognizable, in the penultimate metamere, only within the parietes of the ventrum. Tail regenerates, in spite of the high incidence of posterior amputation, were not found.

In the (a) worm, loss of setae with resorption of setal follicles, and elongation of the last segment, are regarded as external indications of a process of reorganization, as one result of which a new growth region, in addition to an anus, is reestablished in place of that which had been lost by amputation. In the (b) worm the penultimate segment is regarded as one that had already been marked off (by an intersegmental furrow from a reestablished growth region), but in which equatorial setae, one of the stigmata of a metamere, had not yet been sufficiently developed to be externally visible except in the ventrum. Differentiation of the new metamere had not yet been fully completed. Further, the length of the terminal (growth) region is such as to indicate possibility of production of yet another segment. If these interpretations are correct, *P. agrestis* presumably does not, at least ordinarily replace lost posterior portions at levels behind 62/63

by the supposedly usual process of tail regeneration. Instead, a growth zone is reconstituted that may produce new segments, but only slowly and one at a time. In new segments so produced, the usual differential stigmata of regeneration, so easily recognizable in long tail regenerates that have been produced by a much more rapid process, may well be lacking.

The penultimate segment (counting anal region as a segment), in several specimens that presumably had not undergone posterior amputation, had no externally visible setae and no vestiges of former setal pits were recognizable. Both ante- and pen-ultimate segments in another specimen (of 100 segments) were similarly incompletely differentiated. In the rather small anal region of two specimens (of 100 segments each), a short rudiment of an intersegmental furrow is present, in the ventrum (1) or dorsum and then with a rudiment of a dorsal pore. These conditions are regarded as indicating that new segments may be produced, even in unamputated adults, by a slow, one-at-a-time method.

Remarks. The clitellum seems to be fully developed in every specimen. Nevertheless no spermatozoal iridescence was noticed on any male funnel of the six dissected specimens. Nor was spermatozoal iridescence recognizable in any of the thirty-five spermathecae. If sperm are produced they cannot, in absence of male terminalia, be transferred to another individual in copulation. Every specimen in a fair-sized sample being anarsenosomphic, reproduction must take place by self fertilization or parthenogenesis, with the latter more likely because of apparent absence of mature sperm in the probable breeding season. In either case, introduction of a single worm, even a single cocoon, theoretically could have enabled establishment of *P. agrestis* in the arboretum.

Presence of a full set of seminal vesicles, and of a complete battery of spermathecae, all now of no apparent use in reproduction, on a principle of economy, indicates that the anarsenosomphic development in this species has been recent.

DISCUSSION

During the summer the population of the pond periphery quite obviously had increased considerably. Exposed but still saturated margins were almost covered with castings of *Sparganophilus eiseni*,

the only species found (the *rubellus* sites, just at the high water level not re-examined).

In the original leaf pile, *E. rosea* apparently had disappeared, and two species, *E. foetida* and *D. subrubicunda*, absent in the spring, had appeared. One of them, *D. subrubicunda*, had become dominant numerically. *L. terrestris*, however, still remained dominant by sheer volume even though not as common as in the spring.

From the earth of the original peat bog site all worms had been removed in the spring. Several weeks later more than fifty specimens had moved into the disturbed soil from below or round about. Although that same soil still appeared moist in September only seven worms were found in it. Three species, *E. rosea*, *E. tetraedra* and *L. rubellus* were no longer represented, but two, *O. lacteum* and *L. terrestris*, that had been lacking at time of second collecting were again present.

In the newly examined leaf pile, *Pheretima agrestis*, an exotic from Japan (and possibly brought directly from there) was clearly dominant by weight though equalled in numbers by *L. rubellus*.

No cocoons or copulating individuals of any species were found in fall collecting. A clitellum sufficiently mature for cocoon deposition apparently characterized specimens of *L. terrestris*, *O. lacteum*, *D. subrubicunda*, *P. agrestis* and *E. foetida* but appearance of the clitellar region indicated that the reproductive period had ended in *A. arnoldi* and *L. rubellus*. Breeding period in *P. agrestis* is probably in the fall.

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